

LUBRICATION

A Technical Publication Devoted to the Selection and Use of Lubricants

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Heat Exchange as it Relates to Effective Lubrication

STEAM power operations today require steam pressures involving temperatures upward of 900 degrees Fahrenheit. Refrigeration, in the storage of ice cream, or the processing of wool, may necessitate cold conditions as low as fifty degrees below zero, Fahrenheit. From a mechanical point of view both of these extremes are perfectly practicable and readily maintained, provided materials and machinery are designed and selected to develop complete coordination.

Under the classification of materials one must consider lubrication. But a few years ago it would have been impossible to operate machinery under such extreme temperature conditions, for the science of petroleum refining had not progressed sufficiently to produce oils and greases of adequate pliability at low temperatures, and resistant to breakdown under high steam pressure conditions. By attacking this problem from two angles, however, research developed some very interesting facts. It proved that chemical stability, in the presence of certain refrigerants involving sub-zero operation, was probably the most important characteristic in an oil intended for refrigerating compressor lubrication. It proved that close fractionation and removal of low boiling point hydrocarbons materially aided an oil to withstand high temperatures. Both of these features were then considered in selecting the oils to use in compounding greases to meet similar conditions.

This made it possible to change the lubricant, where operating temperatures were inherently

high or low and where change of these latter might be impracticable. In many types of service, however, the operating temperatures of parts in motion with respect to one another can be controlled by circulation of a suitable cooling media. The most familiar example is the water jacket as applied to the automotive engine. Here the continuous circulation of a few gallons of water keeps the cylinder walls and pistons sufficiently cool to assure of good lubrication, yet with no impairment of combustion efficiency. In other words, the contact surfaces are just cool enough, yet no part of the combustion chamber is so cool as to cause reduction in power through loss of heat via the cooling water.

We are not always dealing with internal or enclosed mechanisms however. Viz., in contrast to the automotive or Diesel engine which is typical of the above, exposed chains or wire rope in contracting machinery service will present another extreme,—involving conditions of exposure, low temperatures and the probability of contamination. Here there is no possibility for temperature control, hence the absolute necessity for the lubricant to meet the operating conditions.

All of which leads up to the fact that effective lubrication is most readily accomplished where oil film temperatures can be maintained within a comparatively narrow range. It is no longer necessary for this range to be relatively low; it must however conform with the nature and ability of the lubricant to function dependably

at the prevailing temperatures. Today there is a type or series of lubricants available which is capable of meeting practically any temperature conditions encountered in manufacturing procedure. It must never be assumed, however, that any specific lubricant is all-temperature resisting, but some *one* is usually available to

of engine temperatures especially at low speeds, and furnishes more reserve cooling. Furthermore the added weight of the radiator, pump and cooling medium is not objectionable. In the modern aircraft engine, however, dead load is a vital factor, for it is directly related to pay load. Furthermore the aircraft engine operates

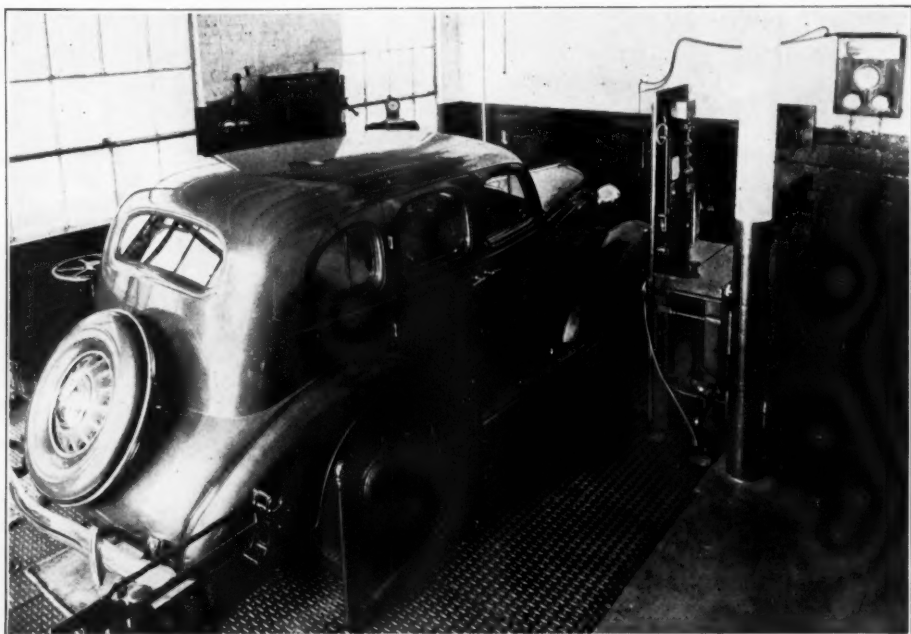


Fig. 1—The Chassis Dynamometer at the Beacon, N. Y., Laboratory of The Texas Company, showing car under test, facing the point of air discharge as discussed on page 18.

meet the existing operating range provided this can be suitably controlled. As we approach the ideal in this regard the load imposed upon the lubricant is materially reduced. On the other hand where a wide range of operating temperatures prevails, the viscosity range of the lubricant will be proportionately wide, with the possibility of drag and increased internal friction at the lower end of the range, and impairment of the strength of the film at higher temperatures.

Temperatures can be controlled in several ways. When dealing with higher temperatures probably the simplest method of accomplishing some reduction is to provide means for natural and constant circulation of fresh air. Usually this is the least costly but at the same time the least effective in the case of stationary operations.

Air Cooling Contingent upon Circulation

Air cooling has been most practicable on mobile machinery such as the automotive or radial type aircraft engine. In the former it has been almost entirely superseded however by water-cooling since this gives better control

under more constant air velocity conditions which are conducive to more complete circulation around the fins which surround each cylinder, to result in adequate heat transfer.

In other words draft either natural or induced is essential to satisfactory air cooling. Stationary machinery can be most effectively cooled by the latter, but as the entire unit is exposed, oftentimes those parts which require cooling to assist lubrication are not subject to complete air circulation, with the result that heat transfer is not effected to the desired degree. Another way of looking at this is to state that the parts to be cooled should be preferably in the same plane with respect to the air stream in order that none of them shall be exposed to heated air from the others. The radial aircraft engine illustrates this idea most effectively.

Water

Water has for years been the most practicable cooling medium due to its relatively high heat-absorbing ability. The desired results can be most positively attained where the water is circulated under pump pressure through suit-

LUBRICATION

able cooling coils or water jackets. On the other hand natural circulation can also be brought about by taking advantage of the thermal properties and the natural tendency of warm water to rise in a circulating system. Certain older types of automotive systems were typical of this idea some ten years ago. The same principle is made use of in steam heating coils as designed for pre-heating of lubricating oils in winter-time rock crusher service and other cold starting operations.

Those advantages which pertain to water as a cooling medium for the working parts of industrial and automotive equipment include:

1. Availability in any quantity in most localities.
2. Low cost and economy in handling.
3. Easy storage.
4. Ready disposition of waste.
5. High cooling effect by reason of its high specific heat or, in other words, ability to take up heat.

In contrast, a distinct disadvantage exists in that should leaks develop between the cooling and lubricating systems, undesirable contamination of the lubricant by water would result. The extent to which this might be detrimental to subsequent operation would depend upon

Sludge is non-lubricating, and frequently of a sufficiently viscous and sticky nature as to lead to obstruction of oil lines, bearing grooves or other parts of the lubricating system. Obviously, this would impair lubrication, due to possible reduction in circulation of the oil.

This latter will also decrease the cooling ability of the oil. This is, of course, only a partial function of the lubricant, but if circulation is maintained at a sufficient rate it will materially aid in reducing bearing temperatures, particularly at the wearing surfaces where overheating would be most detrimental. In this the oil serves as an assistant to the cooling water in maintaining safe operating temperatures.

STEAM COOLING

An interesting contrast to the use of water for cooling purposes has been the attempt to utilize steam for the same purpose in connection with the automotive engine. The obvious purpose, of course, was to maintain engine temperatures at a more constant high level in the interest of promoting greater efficiency in fuel combustion, and thereby better economy. The idea, however, was never perfected to the point of receiving popular acceptance. The difficulty lay in the inability to coordinate engine design with low cost production.

Steam cooling, where a higher range of temperatures is desirable, could be likewise applied to certain industrial operations where oil might be impracticable due to carbonization or where water might flash into steam and cause pressure complications. Obviously, were the cooling jackets or coils designed originally for say 150 lb. steam, and the lubricant for attendant mechanisms selected accordingly (with respect to viscosity, carbon residue content and flash point), quite a constant range of temperatures could be maintained. One could visualize such an application in metal working

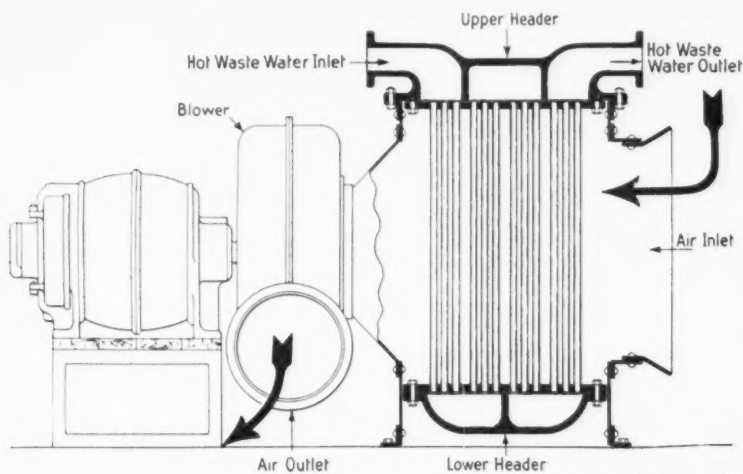


Fig. 2—Sectional view of a Schutte & Koerting air heater. This device is adapted for use with live or exhaust steam, or hot water. As air passes through and across the tubes, it is divided into thin films. The tube arrangement reduces frictional resistance and sluggish air flow.

the degree of refinement of the oil, the design of the machine and the readiness with which it can be flushed.

Water contamination in the steam turbine, for example, would be a very serious matter. There only the most carefully refined oils are used, for they must have the least possible tendency to emulsify with water, otherwise emulsification and subsequent agitation in the presence of air would cause sludge formation.

ing machinery, in the cement mill and perhaps in oven or dryer design.

OIL COOLING OF DIESEL ENGINE PISTONS

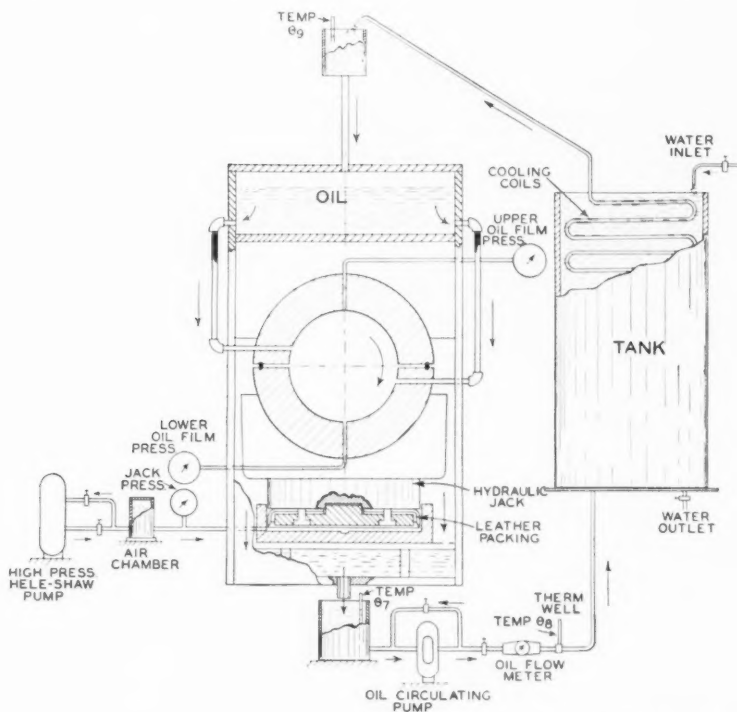
The development of the high speed Diesel and the adaptability of this medium of power generation to service comparable with the steam turbine, has required careful thought concerning efficiency in operation, positive lu-

brication and dependable cooling. Probably the most advanced idea has involved the possibilities of oil as a cooling medium for the pistons. There is a definite advantage to this idea wherever it can be practically applied in that lubrication is, in turn, protected. In brief, the

the quality of the lubricant in the crankcase will normally not be materially lowered, especially if the oil which is used for cooling is of a sufficient degree of purity. In other words, oil cooling insures that lubrication will not be impaired due to possible development of non-lubricating sludges. Mineral oils, however, have a considerably lower relative cooling ability compared with water, due to their lower specific heat.

Protected lubrication is of material importance in the operation of the modern Diesel engine. Construction of virtually all the large high speed engines requires cooling of the pistons. This can, of course, be accomplished by either water or oil. Their relative advantages have already been mentioned.

Oil as a cooling medium, however, is limited by the design of the piston. This must be such as to insure continuous turbulence of flow within the cooling medium in order to prevent, as far as possible, the formation of heat-resisting films along the walls. Should such films develop, carbon deposits may be the ultimate result, especially at the more highly heated parts of the piston. To prevent this becomes a function



Courtesy of Westinghouse Electric & Manufacturing Co.

Fig. 3—In laboratory research on bearing design it is quite as important to maintain the bearings under test at predetermined temperatures, as in actual plant operation. Above is therefore shown an arrangement of testing equipment as devised by Westinghouse. Note in particular the provisions for oil cooling and location of the tank and other necessary equipment.

Diesel designer along with the operating engineer is taking the science of lubrication more seriously than ever. Naturally it covers a multitude of conditions, both structural and operating; it requires considerable familiarity with petroleum lubricants; and by reason of the prevailing high temperatures the principles of heat transfer must be thoroughly understood.

Heat transfer is directly related to lubrication. It is obvious that in an internal combustion engine such as the Diesel, where cylinder walls and pistons are directly exposed to burning gases, lubrication of these surfaces must be carried out under most detrimental conditions. Well refined straight mineral oils possess quite satisfactory characteristics as heat transfer media in that they will have but little tendency to gum or develop heat resisting deposits, especially when subjected to wide temperature variations. Furthermore, they possess the distinct advantage in that, should leakage develop,

of the designing engineer.

LUBRICATING OIL HEAT EXCHANGERS

Mineral oil has also been used as a cooling medium in connection with heat exchanger types of lubricating oil coolers. Such equipment is adaptable to steam turbine service; for example, where a considerable volume of oil must be continuously cooled. Here again, mineral oil, even though it may not possess as great a cooling ability as water, will serve to protect lubrication more effectively, should leaks develop within the cooler.

Oil has likewise proved to be adaptable to process heating instead of steam or hot water. The usual conditions of application will enable economical construction, for low pressures are an adjunct, along with temperatures ranging up to perhaps 500 degrees Fahr.; features which permit the use of standard equipment and fit-

LUBRICATION

tings. In other words, low pressure operation requires no extra precaution to prevent leakage, which might result from the effect of pressure alone. Due to the inherently dangerous nature of hot oil, however, the utmost precaution must be taken to prevent leakage due to high tem-

precaution against leakage, for usually the grade of oil used for preheating will be inferior to the lubricating oil involved.

An oil heating system must be so designed as to prevent accumulation of gas. This can be accomplished by means of a suitable vent

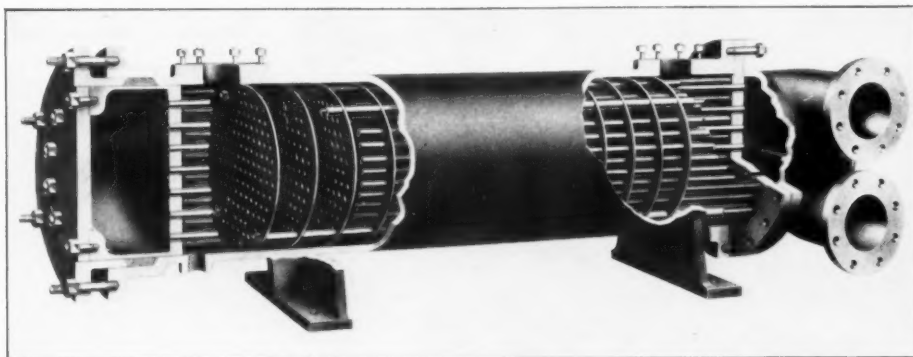


Fig. 4—The Grisco-Russell style TM multiwhirl heat exchanger for cooling lubricating oil from turbine bearings, etc. Hot oil is continuously circulated through the shell under pressure, being brought into intimate contact with the cooling surface by baffles. Cooling water is passed through the tubes in one or two passes.

perature-effect on piping materials or fittings. Oil leakage coming in contact with certain types of materials being processed might also cause

attached to an expansion tank. Elimination of gas accumulations prevents pressure build-up and assures of more uniform heat transfer.

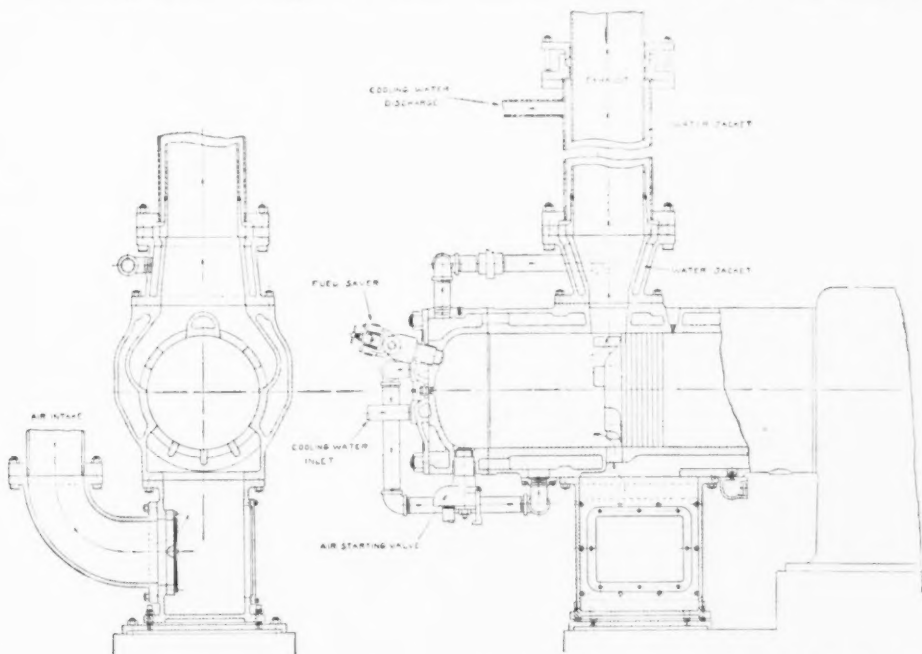


Fig. 5—Details of cylinder water cooling equipment on a Clark two cycle gas engine. Note in particular the water jacketing of the exhaust. Circulation of about 90 degree water at a rate of from 50 to 60 gallons per minute per power cylinder is suggested for most effective cooling.

damage through staining or discoloration. The use of hot oil applied via a suitable circulating system to a lubricating system also requires

METHODS OF COOLING

Cooling of stationary materials or machinery by air can best be accomplished by locating in

a stream of fresh cool air. Such a stream can be maintained and controlled with regard to intensity and velocity by means of an electric fan or blower. In turn, its temperature can be regulated by inserting a suitable radiator in the air stream. We have already mentioned how the design of the radial aircraft engine provides

velocities comparable to road service could be attained by operating a centrifugal fan or blower and blowing air over the front of the car under test. The operating speed of the fan with respect to the speed of the traction drums on which the car runs is such that at any car speed the velocity of the air striking the front

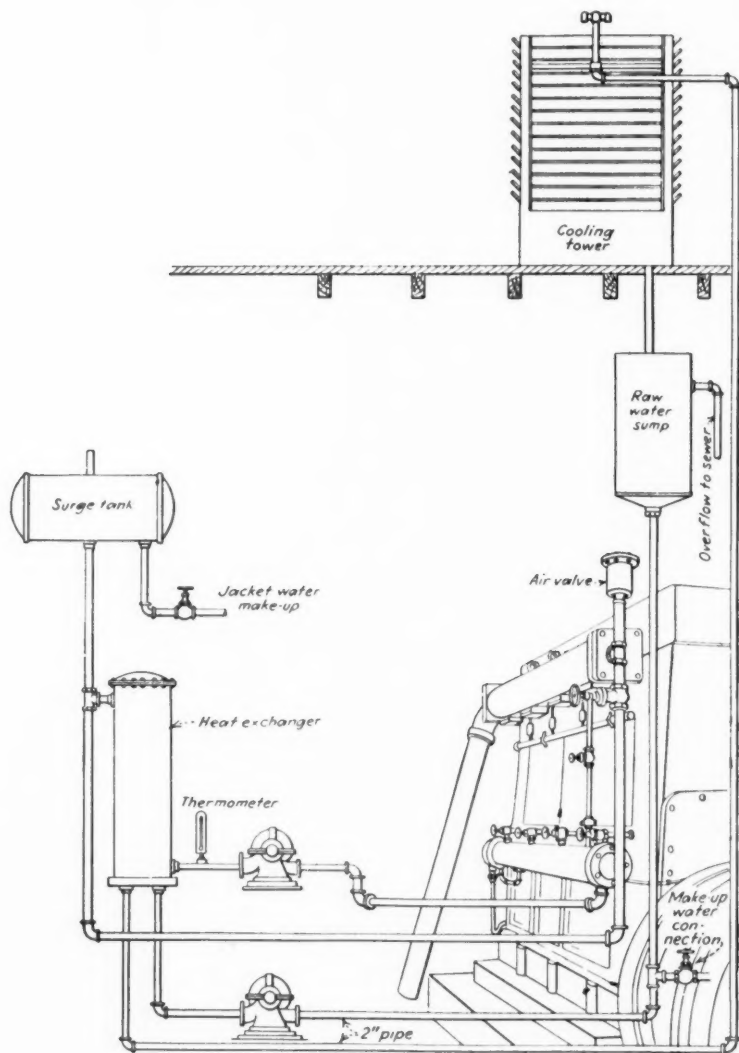
of the car will be very nearly the same as the actual speed the car is making on the drums. This assures cooling of the radiator and especially the engine oil pan equivalent to that of running at the same speed on the road. See Fig. 1.

The size of the fan in this installation had to be carefully determined so that the power required to drive it at any speed would be practically the same as the power required to drive a car against still air at the same speed. It is interesting to note that the power required to overcome wind resistance is very nearly the same for any type of car, inasmuch as the width and height, regardless of style is, after all, dictated by the size of the average person; thus the frontal area of all cars is surprisingly uniform. Furthermore, "streamlining" has made very little difference in the power required to overcome wind resistance.

In realization of the fact that temperature control of the air used for cooling purposes is highly important, provision has also been made at Beacon to deliver this air at any atmospheric temperature up to 130 degrees Fahr. In operation, therefore, the air passing to the fan can be taken directly from outdoors, re-circulated from the room

through a grating in the floor, or over banks of steam radiators, if necessary, prior to passage to the fan. The amount of steam supplied to these radiators is regulated by a throttle valve located near the station of one of the operators.

Positive control of air is made possible by operation of two sets of sliding doors, one of



Courtesy of Diesel Power Data Service

Fig. 6—A closed cooling water system for a one-engine plant. The raw water steel sump is inside the building to prevent freezing. The jacket water sump tank is connected to the return line from the engine. Note relative location of pumps and necessary connections.

for air cooling. Now let us see how the modern research laboratory does the same thing in studying automotive equipment on the chassis dynamometer,—a case of mobile equipment operated in stationary position.

At the Beacon, N. Y., research laboratory of The Texas Company, it was found that wind

LUBRICATION

which can be used to regulate the amount of air re-circulated through the steam radiators, the other being arranged to open the fan suction directly to the outside fresh air. Both these sets of doors can be controlled by the operator at the same station as the steam throttle valve, at which point the temperature of air being directed against the car is indicated by a thermometer magnified by a suitably located lens.

PUMP CIRCULATION

Fluid cooling media however must be handled by pumps. In other words rapid circulation to enable constant renewal of the cooling film on the surfaces to be cooled is essential to efficient heat transfer. Furthermore, rapid circulation with adequate turbulence reduces the possibility of formation of stagnant films which may readily serve as insulation. Another means of preventing this is to employ cooling coils or jackets with comparatively smooth surfaces.

Circulation of cooling water or oil at uniform velocity commensurate with the rate of heat transfer desired can be maintained most effectively by use of pumps. The type and size depends upon the size of the installation and the volume of coolant to be circulated. Under general conditions of industrial plant or engine operation, the gear, rotary or centrifugal pump is used. The reciprocating piston or plunger pump is, of course, also adaptable, but in view of the fact that it will normally require steam for its operation it is but little used in connection with oil cooling.

Circulating pumps can be driven either directly by the machine which they are to serve, by an independent electric motor or some other means of power transmission. In the automotive engine, it is customary to use a gear pump, driven by belt or chain connection from the main shaft. Where industrial bearings are involved, however, or where a more considerable volume of cooling media must be handled, independent means of drive is frequently adopted. In marine service, on the other hand, the reciprocating steam pump is widely used.

Rotary motion as embodied in the gear, screw type or centrifugal pump is distinctive in that

it requires no valves, springs or other small parts to wear out or become inoperative. Furthermore, there are normally no internal parts that require lubrication. In other words, where a cooling water pump, for example, may be installed externally, the only parts to be lubricated will be the bearings. With an internally

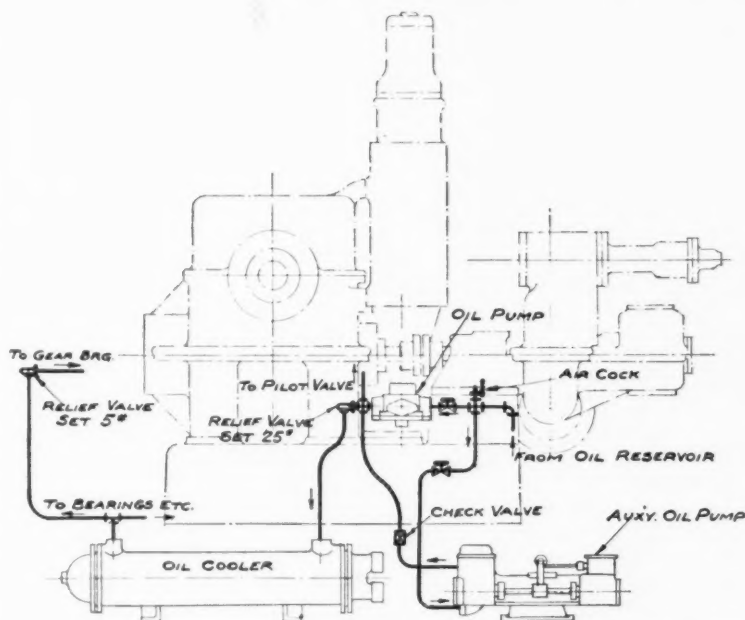


Fig. 7—Diagram of the oiling system of a De Laval reduction gear set. Note necessary connections to oil cooler and provisions for complete circulation of the oil.

Courtesy of De Laval Steam Turbine Co.

installed gear pump, on the other hand, lubrication is brought about from the machine itself.

Centrifugal Operations

These are involved wherever one or more rotors or impellers, revolve in a fixed plane within a suitable air-tight casing. The fluid to be handled is received at the hub or center of the impeller, pressure being acquired as it is impelled outward to the circumference by means of suitable blades. Dependent on the type, fixed discharge valves are used similar to stationary nozzles, or a suitably spiral casing is employed for such purposes. Volute pumps are of this latter type. Centrifugal pumps are of definite value where a considerable volume of cooling water is to be handled under variable pressure and volume conditions. They must always be designed to operate free from air leaks, however, otherwise there will be a reduction in efficiency. Furthermore, the pump discharge must be of such a diameter as to insure the delivery of the fluid with a minimum of friction, the operating speed must be commensurate with the pumping head and there should

be a minimum of sharp bends and elbows in any piping involved. *Viz.* The simplicity of design of the automotive type of pump.

Rotary Design

Where there are two rotating elements, involving gears, screws, pistons, impellers or

from through gear, chain or belt connection. In pumps of this type it will, of course, be essential to lubricate the bearings, for the pumps cannot be expected to function effectively as an aid to lubrication if they are not, in turn, properly lubricated.

Bearing design may vary to some extent, according to the type of pump and its intended service. In turn, one may therefore be confronted with specific problems according to the operating conditions. They require serious consideration and cannot be passed over as mere instances of ring oilers, ball bearings, etc., or plain babbitted bearings served by oil or grease cups.

The ring or collar oiler is widely used on horizontal jobs or for oil circulation to the bearings of centrifugal pumps. Its specific advantages include economy, cleanliness, and ability to maintain uniform and automatic lubrication requiring little attention.

The design of a typical ring or collar oiler comprises a bearing housing

which is built with a reservoir and a slot of sufficient width and depth to permit one or more rings or collars suspended from the shaft to revolve therein. As a result, with the revolution of the shaft, these elements, being subject to rotation, carry a flood of oil to the top of the shaft from whence it is able to flow into the bearing oil grooves and throughout the clearance space. This assures of complete distribution.

Unless the design provides otherwise, oil after being passed through any such bearing will flow out to the end or ends of the shaft through a suitable return chamber which is part of the bearing housing, back to the oil reservoir below. Ring oilers are not usually recommended for bearings below two inches in diameter, especially where high speeds are involved, due to occurrence of excessive slippage of the rings, and the possibility of oil foaming where reservoir capacities are limited and aeration may be restricted.

This is one of the simplest yet positive methods of lubrication, whereby the bearings are flooded with a considerable excess of oil over the amount that would theoretically be necessary to furnish the requisite oil film. By flooding the bearing with oil the latter serves not

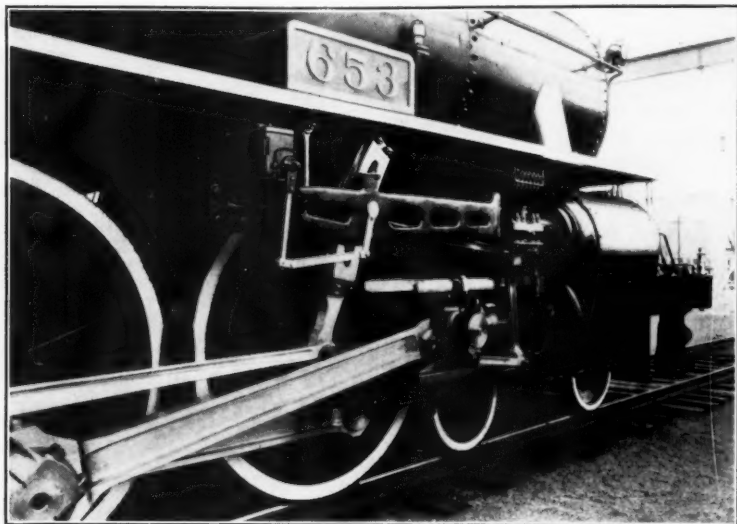


Fig. 8—Showing a typical installation of a Bosch automatic positive force-feed lubricator in locomotive service. On such jobs it is usually beneficial to provide a steam connection for heating the oil in the lubricator in cold weather to facilitate pumping.

Courtesy of United American Bosch Corp.

cycloids, the resultant pumps are regarded as being of the rotary type. The principle is quite akin to that of the geared pump, the matter of teeth or lobes being the criterion. The most common type of such a pump is the geared device as used in connection with the automotive engine. While it serves chiefly as a lubricating pump it is important to remember that the volume of oil which it delivers to the wearing elements also insures a certain amount of cooling. This same result is obtained in the lubrication of certain types of steam turbines using a pump of similar construction.

Relation of Design to Lubrication

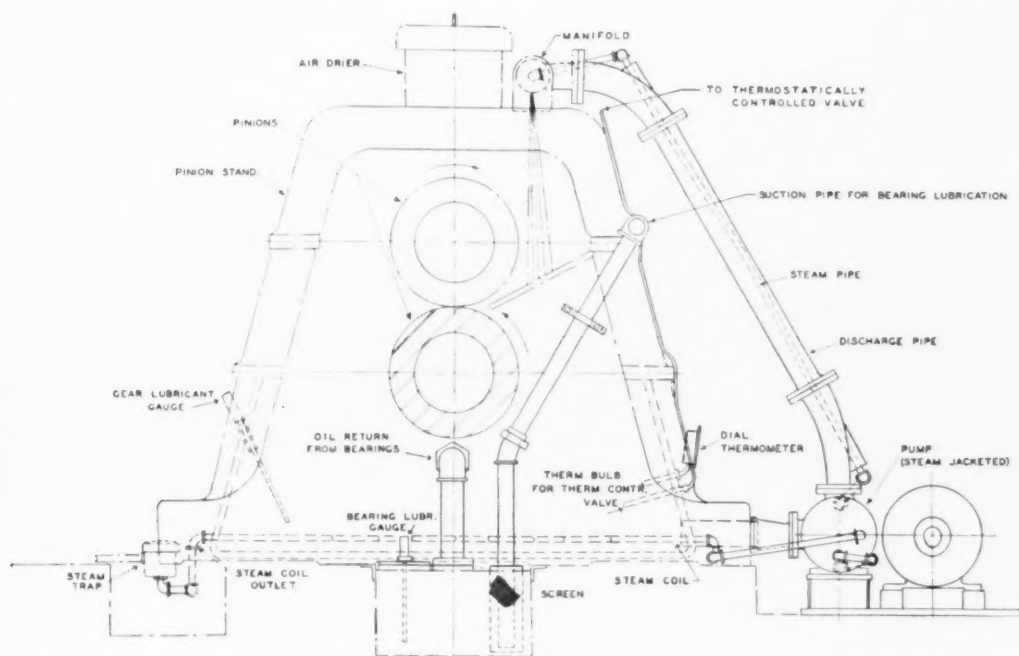
Lubrication of the bearings or other mechanisms of pumps used for circulating cooling water or oil, must be studied from the viewpoint of their location. Where a pump is built into the machine which it is to serve, it will normally be designed for the handling of oil, the function of which is both to serve as a lubricant and a coolant. At the same time, this oil serves to lubricate the pumping elements.

Where either a centrifugal or rotary type of pump is designed for the handling of cooling water, it will be installed adjacent to the main machinery, but usually driven directly there-

LUBRICATION

only as a lubricant, but also as a cooling medium to carry away part of the frictional heat developed, thereby reducing the temperature of operation. If the oil reservoir in the base of the bearing has been properly designed and is of sufficient capacity, this over-heated oil will then

of the lubricant is to prevent corrosion of the highly polished surfaces. As a result, wherever possible, the housing should be oil-tight for thereby can we reduce the resistance to shear of the lubricant and in consequence the internal friction that will be developed during operation.



Courtesy of The Falk Corporation

Fig. 9—Lubrication piping for a Falk 20 x 36 pinion stand. This is a thermostatically controlled pre-heating system whereby the lubricants under circulation can be maintained within very accurate temperature ranges. This is of definite advantage in steel mill service where atmospheric temperatures may vary very widely. Pre-heating is of definite advantage on cold starting. Conversely the above system can be used to permit cooling in extremely hot weather.

have ample opportunity to become cooled by contact with the reservoir walls after each circulation. This flood of oil will also serve to wash out any grit, dirt, dust or metallic particles that may have gained entry, thereby another cause of wear will be largely eliminated. On account of this washing action of the oil, however, the reservoir will gradually tend to accumulate a certain amount of sedimentary deposits. Therefore it should be flushed out and cleaned at intervals, the old oil being replaced with new or purified oil.

In contrast with the sleeve type bearing, ball bearings or sometimes those of the roller type are also employed on circulating pumps. Probably the most noteworthy of the smaller installations involves the automotive engine cooling water pump. Developments in design have taken full advantage of the principle of rolling motion, and the possibility of planning for long-time lubrication with the need for practically no attention. Here, however, it is always essential to remember that one of the chief functions

Under such conditions a comparatively fluid oil is preferred.

Wherever leakage is possible, however, a grade of light to medium grease should be used which will have just enough body to cause it to remain in the bearing housing. Lubricating attachments such as oil or grease cups are usually unnecessary on such bearings, it being customary to charge or fill the housing and raceways with the proper grade of lubricant, through a suitable opening or fitting which can be effectively sealed or plugged during subsequent operation to prevent the lubricant from flowing out. In general, one charge of oil to a roller or ball bearing equipped with an oil-tight housing should last for a period of several months. Where grease is required, however, it should be renewed according to the extent of seal which is maintained. The pre-lubricated, sealed-type bearing should function successfully for an extended period of time without any attention whatsoever.

HIGH TEMPERATURE SERVICE

Under conditions of continued high temperature, it is highly essential to use lubricating oils and greases which have been especially refined to insure maximum resistance to breakdown, otherwise chemical change and deposition of more or less carbon may occur, to lead to accumulations in oil grooves, around piston rings,

will be composed of from 83 per cent to 87 per cent carbon, with 11 per cent to 14 per cent hydrogen. The balance of any such product will include small quantities of sulfur, oxygen and in some types nitrogen according to the geological formation from which the oil has originated.

Carbon, as an inherent component of all petroleum products, by reason of their complex hydrocarbon make-up, must remain as nearly as possible in this combined form if the products are to function effectively. Particular effort has been made by the petroleum industry to produce lubricating oils which will resist breakdown and retain their original hydrocarbon formation in actual operation.

Chemical change is largely responsible for deposits of carbon plus dirt, as, for example, on the valves or in the discharge lines of an air compressor. It is impossible to get away from this phenomenon, for lubricating oils, regardless of their base or nature, will develop volatile products and carbon when subjected to temperatures considerably above the flash point. On the other hand, the extent of this reaction will depend upon the length of time the oil is exposed to such heat. Hence the value of adequate jacketing to insure proper cooling.

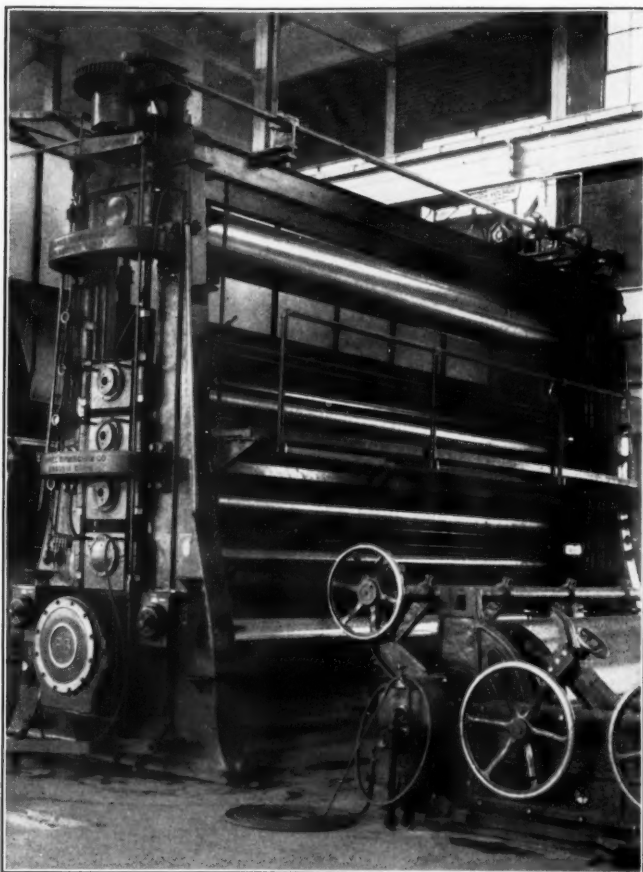
Types of Carbon

In air compressor or internal combustion engine service, carbon in its true form may develop in the cylinders in a hard mass, or it may be produced in the shape of dust and pass out with the air or exhaust. In the latter case, it will often collect in pockets, elbows, or on sharp edges and become mixed with dirt which has gained entry, as well as

with oil which has been vaporized in the cylinders, and later condensed at these points.

Inasmuch as carbon is a poor conductor of heat, when deposited in cylinders or around piston rings, it may become heated considerably above the temperature of the cylinder walls. This condition ultimately may be hazardous if allowed to continue. Furthermore, there will be a possibility of accumulations developing on the valves and valve seats, and in the ends of the cylinders. This may cause valves to leak, frequently resulting also in cutting of the latter and scoring of the cylinders.

Where deposits of dirt, gum, or carbon



Courtesy of The Pusey and Jones Corp., and Farrel-Birmingham Co.

Fig. 10—A typical paper mill calender stack showing lubricating oil and water connections. At this point in the manufacture of paper, pressures and temperatures are very high, calling for considerable care in lubrication and maintenance of uniform oil temperatures.

or in other parts of the lubricating system. This will be especially true in connection with the internal combustion engine, the air compressor, and in some types of steam engines. Other examples of where this may occur will be in the operation of the textile calender, the dryers in the paper industry or where kiln treating or metal working is practiced.

Inasmuch as carbon deposits may therefore be expected to develop into a decided detriment, in connection with the maintenance of effective lubrication, study of the manner in which they occur in petroleum lubricants should be of interest. The average petroleum product

LUBRICATION

become localized in the valve passages and bends of piping of a compressor system to such an extent as to restrict the opening through which the compressed air has to pass, temperatures may be produced capable of eventually causing failure, especially if any part of the system is weak. In view of the fact that distilled oils, where properly refined, show the least tendency toward direct carbonization and the development of carbonaceous matter, they are generally accepted as being best suited to air compressor and internal combustion engine service. Furthermore, any such direct carbon as may be formed through excessive use of such oils is normally of a light, fluffy nature. Carbon deposits formed from improperly refined or unsuitable oils, on the other hand, are often of a hard, flinty nature. Any oil will accumulate dust if the air is dirty and no provisions are made for filtration or cleaning.

Flash and Fire

It is of importance to study the flash and fire points of lubricants where certain phases of exposed high temperature lubrication are involved; that is, where lubricants must be more

Exposure of lubricants to direct heat involves the possibility of abnormal vaporization of the more volatile constituents, to result in accumulations of non-lubricating carbon residues.

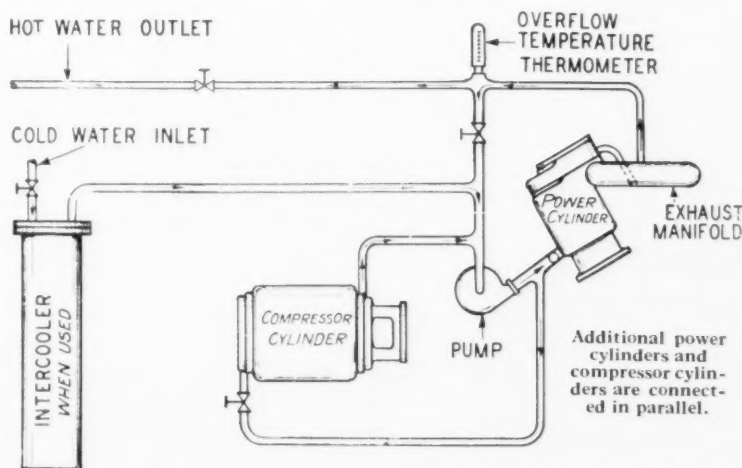


Fig. 11—The cooling system of an Ingersoll-Rand type XVG gas engine-driven compressor. By using a built-in water pump, some of the cooling water is re-circulated through the engine, resulting in increased water velocities and a smaller temperature difference in the power cylinders.

Continued exposure of these latter to high heats will cause coking of such residues, with subsequent clogging of oil grooves or other vital parts of the lubricating systems, etc.

As a guide to the lubricating ability of any oil, flash and fire point readings are of value only as indicators of the relative initial volatility. The flash point should not be regarded as a definite temperature at which boiling

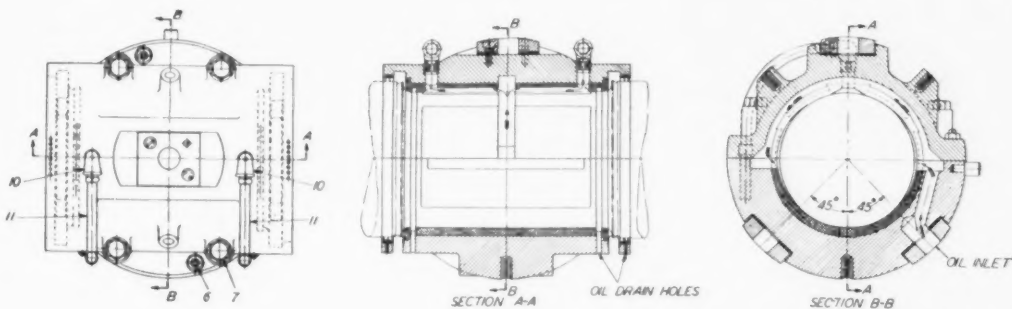


Fig. 12—An arrangement of Westinghouse bearing designs. Two orifices are provided which can be varied to increase or decrease the flow of oil through the bearings for cooling purposes. Arrows show path of oil through the bearing clearances.

or less exposed to flame, steam or electric heating mediums. Instances of this would involve the lubrication of open-hearth charging equipment in the steel industry, the lubricating of steam engines functioning on super-heated steam, automatic bake oven equipment in the baking industry, and the operating mechanisms in metal-working.

takes place, or at which a petroleum product may pass even partly over to the vapor stage.

The extent to which vaporization of a motor oil, for example, may occur at temperatures below its apparent flash point will largely depend upon the proportion of low flash point or high volatility hydro-carbons which it may contain and the extent to which the surface of

the oil may come in contact with freshly heated air. This may be a very important factor where improperly refined oils are used, for it will lead to abnormal consumption and a false impression as to the actual cause.

In such service the motor oil, therefore, must not only be capable of functioning without an undue amount of vaporization at engine crankcase temperatures, but it must also burn cleanly at those higher temperatures, to which the tops of the pistons are exposed. Comparatively high temperatures also prevail at the upper sections of the cylinder walls. Here, however, lubrication ceases to be a function on the occurrence of the explosion stroke.

In view of these conditions, the crankcase temperature is normally regarded as the temperature of the engine bearings; a fair average the year round would be in the neighborhood of 130 degrees Fahr., although in warm weather, under hard service conditions, the crankcase temperature may rise to as high as 250 degrees Fahr. 130 degrees Fahr., has been chosen as the standard temperature for the determination of viscosity of oils used under the lower range. For oils used under hard driving conditions or in hot summer weather 210 degrees Fahr., has been taken as the standard.

Cylinder wall temperatures, however, will be considerably higher, the mean average being in the neighborhood of 250 degrees Fahr., at the upper parts of the cylinders. Of course, temperatures up to 300 degrees Fahr., may be encountered, but the actual matter of lubrication at such points becomes an almost negligible factor.

Relation to Carbon Content

Flash and fire are frequently indicative of the probable carbon residue content. In other words, with oils of approximately the same viscosity, frequently the higher the flash and fire points the higher one can expect the carbon residue content to be, especially if the oils are not highly refined.

In Air Compressor Service

The heat developed by compression in air

compressor service also requires consideration in evaluating the importance of the flash points of lubricating oils for air compressor service. Oils of the proper consistency which leave unusually low carbon residues are much to be preferred to oils of high flash point. Certain engineers, however, in their eagerness to secure oils of high flash point will frequently overlook this matter of subsequent carbon deposits.

It is sometimes assumed that a high flash point is a desirable quality of a lubricating oil for air compressor service. The thought is that a high flash point will prevent the loss of oil from the cylinder walls through evaporation, thereby lessening the danger of explosions. Laboratory tests on high quality, light body lubricating oils having a flash point between 310 and 325 degrees Fahr., have shown however, that negligible quantities are distilled off up to a temperature of about 615 degrees Fahr., at atmospheric pressure.

In other words, the rapidity of evaporation of an oil, as well as its tendency to carry oil vapors from the cylinder wall film over to the discharge pipes and intercoolers is not governed by the flash point alone. Moreover, even with an oil of too high a viscosity for compressor lubrication, a temperature of about 600 degrees Fahr., would not generate sufficient vapors to form an explosive mixture. Since the discharge temperatures in air compressors range in the neighborhood of 325 to 375 degrees Fahr., and since the cylinder walls are always jacketed it is evident that the oil film on the wall has a temperature lower than the discharge air.

Resistance to breakdown is obviously most essential. It assures against loss by vaporization, objectionable increase in viscosity and carbon formation. It is the province of the petroleum chemist to consider these requirements in planning refinery procedure. Later, in service, the machine designer with the cooperation of the operating engineer, can materially assist the lubricants used in developing most positive lubrication, if means are provided, to prevent abnormal increase in operating temperatures by adequate provisions for heat exchange.